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Documentation of Methods Used to Create
Lithology Coverages for a Part of the
Equus Beds Aquifer
Final Version

by

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General Overview

The purpose of this report is to describe the methods used to create a set of ARC/INFO lithology coverages for a portion of the Equus Beds Aquifer in central Kansas. These coverages were created to help assess the pollution potential of the Equus Beds Aquifer from non-point source contaminants such as nitrate in Harvey County. Their emphasis is on lithologic descriptions of shallow stratigraphy that should affect the rate at which solutes will move from the land surface downward into the aquifer.

The coverages are based on descriptive well logs from Kansas Geological Survey Bulletins and Water Well Completion forms (WWC-5) that are archived at the Kansas Geological Survey (KGS). When analyzing these coverages users should keep in mind that the locational information and lithologic information were derived from published well logs and the WWC-5 forms. The accuracy of the locations is therefore some function of the accuracy of the legal descriptions provided for the wells and the methods used to convert these legal descriptions to real world coordinates. The precision of the lithologic representations in the coverages is a function of the accuracy and detail provided by the well log descriptions and the interpretations of the author. While the coverages have been quality checked for accuracy, the checks were based on comparisons with the original logs. Logs with obvious errors were excluded from the final coverage but the possibility of mistakes in the original logs can not be ruled out. The coverages provide a reasonable depiction of the spatial variability of aquifer lithology across township-scale or larger areas, but they may not accurately depict the stratigraphy at a particular site. It should be remembered that there is no substitute for high quality, site-specific lithologic descriptions.

Areal Extent

The coverages were compiled to study relationships between stratigraphy and groundwater nitrate concentrations in Harvey County. More specifically, as the Equus Beds Aquifer underlies only the western 9 townships of Harvey

County, these townships represent the general focus area of the coverages. To prevent edge effects when contouring the lithologic information, a two-mile wide buffer strip of wells was also included from surrounding counties. The areal extent of the lithologic coverages is shown in figure 1. It includes townships T22s-T24s, ranges R1w-R3w plus a two-mile buffer strip around these townships that includes parts of Harvey, Marion, McPherson, Reno, and Sedgwick counties.

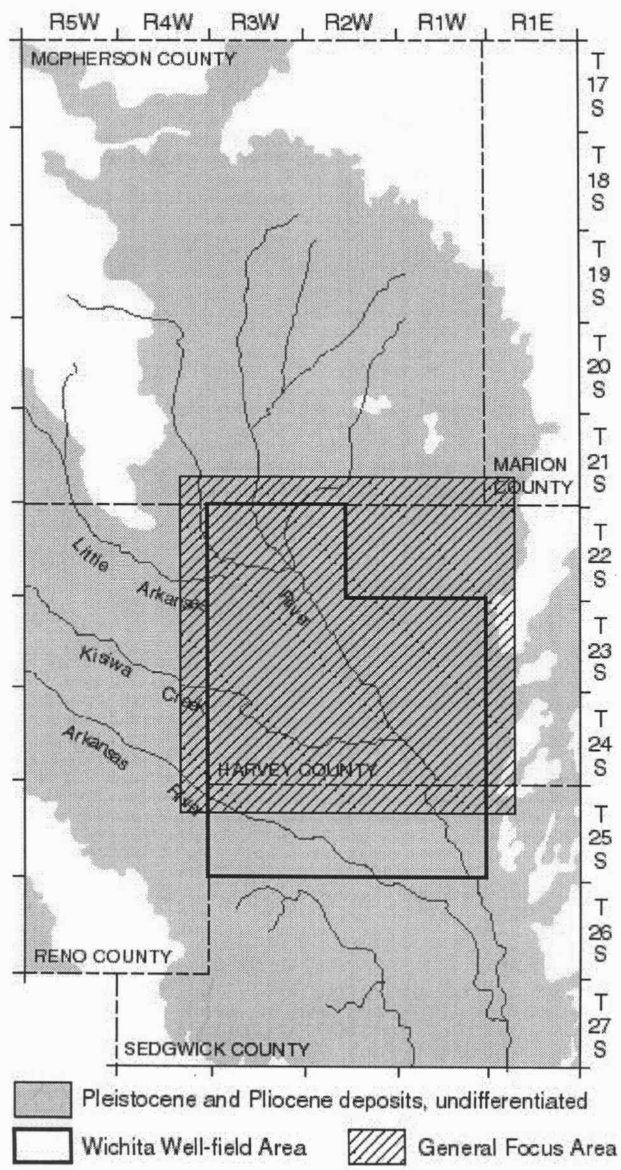

Figure 1. The areal extent of the lithology coverages is the General Focus Area above. The areal extent of undifferentiated Pleistocene and Pliocene deposits that make up the Equus Beds Aquifer and the Wichita Well Field are also included. Base map modified from Stramel, 1966.

Building the Coverages

Well locations

Well locations for the lithology coverages were obtained by entering the U.S. Public Land Survey legal descriptions from each well log into an ASCII text file and then using the LEOII program (Ross, 1994) to calculate longitude and latitude coordinates for each well point location. Locations were entered to the nearest ¼ subdivision provided in the legal descriptions. The locational accuracy for the points in the coverage, assuming that the legal descriptions are correct, is somewhat variable. For wells that were placed in the center of a subdivision (i.e. near center of NW1/4 of Section 24, Township 22s, Range 3w), locations are probably accurate within a few tens of feet. For wells that are not near the center of a subdivision, locations may be accurate within a square having dimensions of the smallest subdivision described. Figure 2 shows an example of the potential variation in location for a legal description written to four subdivisions (SE ¼ of the SW ¼ of the NE ¼ of the NW ¼). All four of the well point locations depicted in figure 2 are within the same box that is 1/16th of a mile wide on each side represented by the above legal description. The location of each well is therefore only accurate within a circle having a radius of 233 feet which is the distance from the center point of this idealized subdivision to one of its corner points. If the legal description contains fewer subdivisions then it is likely that it is even less accurate.

The limitations on locational accuracy and the variability this causes in distances between actual points are two of the primary reasons why the lithology coverages are adequate for illustrating the broad-scale variations in stratigraphy but not site specific variation. It should be noted that improvements in locational accuracy would require a detailed survey of well locations. While this could be accomplished using GPS, it would require a serious time commitment by interested parties.

For the purposes of these well log coverages the LEOII derived locations were deemed "good enough". The longitude and latitude coordinates for each point were used to create an ASCII text file in ARC/INFO generate format.

These coordinates were then used to create point coverages in ARC/INFO. The point coverages were then projected into a Lambert Conformal Conic Projection designed to limit distortion within the study area (Appendix A).

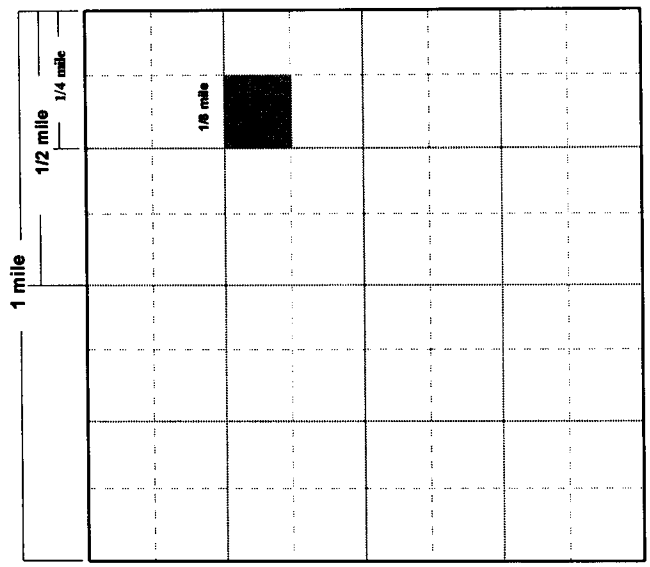

Figure 2. Locational accuracy of point locations derived from legal descriptions from well logs using the LEOII program.

Equus Beds Aquifer Lithologies

The sediments that comprise the Equus Beds Aquifer were some of the most intensively studied Quaternary formations in the state of Kansas from approximately 1930 to 1970. The driving force behind most of this research was the need to determine the amount of water which could be pumped from this aquifer without depleting it (Bayne, 1956; Lane and Miller, 1965; Lohman, 1940; Lohman and Frye, 1940; Lohman, 1942; Petri et al., 1964; Stramel, 1956; Stramel, 1967; Williams and Lohman, 1947; Williams and Lohman, 1949). The focus of this early research was largely on the thick sand and gravel strata within the aquifer that could be tapped by public water supply and irrigation wells to provide large volumes of good quality water.

Tables 1, 2, and 3 contain descriptions of Equus Beds stratigraphy published in KGS Bulletins (Williams and Lohman, 1949; Bayne, 1956; Lane and Miller, 1965). The surficial geology and subsurface stratigraphy of the Equus

Beds includes dune sand, loess, volcanic ash, and alluvium of various textures. The most productive parts of the aquifer are composed of coarse sands and gravels. Finer textured sediments (silts and clays) represent perching zones in the unsaturated zone and aquitards in the saturated zone.

Layers and/or lenses of fine-textured sediments are abundant within and above the aquifer. These fine-textured sediments are important because they can represent major controlling factors on the direction and rate of water movement through the unsaturated and saturated zones. A general description of the physical, chemical, and mineralogical properties of these fine-textured units derived from analysis of existing well log descriptions, more recently obtained core descriptions, soil characterization pit descriptions, and laboratory analyses of samples is included in table 4.

The general descriptions of the stratigraphic sequences in and above the Equus Beds Aquifer found in tables 1-3 are useful because they provide some notion of the range in aquifer properties that can be expected in the study area. Unfortunately they are subjective and difficult to apply in a meaningful or quantitative manner to existing well logs. Also, interpretations drawn about the genetic origin of the sediments that make up the aquifer are less useful than detailed quantitative physical properties would be. The descriptions of the properties of the fine-textured units found in table 4 are in some ways more useful because they are based, at least in part, on quantitative laboratory data. The central problem with both types of lithologic descriptions is that they can not easily be used to address the question of the spatial variability of aquifer properties that influence the direction and rates of water movement through the unsaturated zone or the aquifer.

Table 1. Generalized description of the geologic formations in the Equus Beds Area from Williams and Lohman (1949).

System	Series	Formation	Thickness (Feet)	Physical Character	Water Supply
Quaternary	Recent	Alluvium *Unconformable on older formations*	0-75±	Silt, clay, and cross-bedded coarse-grained sand and gravel containing silt and clay.	Yields large to very large supplies of relatively hard water to wells in the Arkansas and Little Arkansas Valleys. Smaller quantities are obtainable from the Smoky Hill Valley
		Younger dune sand *Unconformable on older formations*	0-50±	Fine- to medium-grained eolian quartz sand. These younger, higher dunes are subject to shifting and blowout and are devoid of vegetation.	The higher dunes are above the water table in most places but constitute a valuable intake area.
	Recent and Pleistocene	Older dune sand *Unconformable on older formations*	0-100±	Fine- to medium-grained, rounded eolian quartz sand, cross-bedded. Several cycles of deposition set off by soil zones. In general these dunes have a cover of vegetation and are subdued in form.	Yields small quantities of soft water to domestic and stock wells. Water contains considerable iron. Forms important catchment area for rainfall.
	Pleistocene	McPherson formation *Unconformable on older formations*	0-260±	Buff to brown silt, clay, sand, and gravel. Channel deposits composed of coarse-grained sand and gravel. Contains Volcanic Ash.	Yields large to very large supplies of moderately hard to hard water especially from channel deposits to municipal, industrial, and farm wells. A few contact springs occur at base.
Tertiary	Pliocene	Delmore formation *Unconformable on older formations*	0-75±	Gray to buff silt, clay and carbonate, fine- to medium-grained sand, small amount of gravel. Material largely derived from Cretaceous and Permian rocks in and near the area of outcrop.	Yields small supplies of relatively hard water to stock and domestic wells
Cretaceous	Comanchean	Kiowa shale *Unconformable on older formations*	0-120±	Dark gray to black gypsiferous shale; gray to buff, sandy shale; soft, cross-bedded sandstone; hard limonitic sandstone; "quartzite"; and thin fossiliferous limestones.	Yields small supplies of hard water to farm and stock wells, and to small springs.
Permian	Leonardian	Stone Corral dolomite	0-8±	Gray, cellular, thin-bedded dolomite on outcrop in McPherson County. Contains anhydrite and gypsum in subsurface westward.	Yields no water to wells in this area
		Ninnescah shale	0-275±	Soft to hard, brick-red shale. Contains some thin beds of gray and green shale, thin argillaceous limestone and gypsum.	Yields meager supplies of highly mineralized water to farm wells.
		Wellington formation	550±	Soft, gray, calcareous shale containing gypsum, anhydrite, salt, and thin beds of argillaceous limestone.	Yields meager supplies of highly mineralized water to farm wells from weathered surface zones and crevices in unweathered beds of shale and limestone.

Table 2. Generalized description of the geologic formations of Quaternary age in Reno, County from Bayne (1956).

System	Series	Subdivision			Thickness (feet)	Physical Character	Water Supply
		Stage	Formation	Member			
Quaternary	Recent		Alluvium		0-60	Silt, sand, and gravel in stream valleys	Yields large supplies of water of poor quality to many wells.
			Dune Sand		0-120	Medium and fine sand in upland areas.	Yields small supplies of water of good quality to wells
	Pleistocene	Wisconsinan	Sanborn	Peoria Silt	0-15	Eolian Silt	Lies above the water table; yields no water to wells
				Wisconsinan terrace deposits	0-130	Silt, sand, and gravel	Yields large supplies of water of good quality to wells.
		Illinoian		Loveland Silt	0-15	Eolian and water-laid silt.	Lies above water table; yields no water to wells.
				Crete sand and gravel	0-40	Silt, sand, and gravel	Lies in part above the water table; yields moderate supplies of water of good quality to wells where below water table.
		Kansan	Meade	Sappa Silt	0-40	Silt and very fine sand; contains Pearlette volcanic ash lentil	Lies above water table in part of area; yields little or no water to wells in area.
				Grand Island sand and gravel	0-100	Sand and gravel and minor amounts of silt	Yields large supplies of water of good to fair quality to many wells.
		Nebraskan	Blanco	Fullerton silt	0-30	Silt and clay and minor amounts of sand.	Yields no water to wells in area.
				Holdrege sand and gravel	0-110	Sand and gravel and minor amounts of silt and clay.	Yields moderate supplies of water of good quality to wells in upland areas where present. Water highly mineralized in channel areas

Table 3. Generalized description of the geologic formations of Neogene age in Sedgwick County from Lane and Miller (1965).

System	Series	Subseries	Stratigraphic Units	Thickness (feet)	Physical Character	Water Supply
Neogene	Pleistocene	Upper Pleistocene	Dune sand (Recent)	0-5	Composed of fine to medium, silty sand.	Lies above the water table and thus yields no water to wells.
			Alluvium and terrace deposits (Wisconsinan to Recent)	0-45	Composed of fine to coarse sand and fine to very coarse arkosic gravel containing only minor amounts of silt and clay that grade upward into clayey silt. Clay balls up to one foot in diameter are common in sand and gravel.	Comprises the most widely used aquifer in the County and yields large supplies of very hard water to many wells. Well yields up to 2,000 gpm can be developed locally. Adjacent to the Arkansas River the water is too highly mineralized for many uses.
			Colluvium (Illinoian to Recent)	0-30	A heterogeneous mixture of silt, clay, sand, gravel and bedrock fragments deposited by slope processes.	Generally above the water table and thus yields no water to wells. Where deposits are thick and contain sand and gravel lenses, wells yielding a few gpm may be possible but would be subject to failure in dry years.
			Loess (Illinoian to Recent)	0-74	Wind-deposited tan to pink-tan, calcareous silt, containing zones of caliche nodules and some sandy zones.	Generally above water table, but locally the basal part is saturated and sandy zones may yield some water to wells.
			Terrace deposits (Illinoian)	0-75	Composed of fine to coarse sand and fine to coarse arkosic gravel that grades upward into sandy silt. Sand and gravel beds locally contain silt and clay lenses, and clay balls up to one inch diameter are common.	Well yields of 500 gpm of good quality water are generally available from the deposits, and locally yields up to 1,000 gpm can be obtained.
		Lower Pleistocene	Undifferentiated deposits (Nebraskan and Kansan)	0-157	Composed o light tan to light gray, commonly sandy, silt and clay, fine to coarse sand, and fine to coarse arkosic gravel. Locally contains a lenticular bed of volcanic ash, the Pearlette ash bed of late Kansan age.	Yield large quantities of good quality water to wells in the Arkansas Valley that are screened in multiple porous zones and penetrate the complete section of unconsolidated rocks. The water is highly mineralized locally near the Arkansas River. Where present in the uplands west of the Arkansas Valley, well yields up to 50 gpm are possible locally.
	Pliocene ?		Ogallala (??) Formation	0-150±?	Composed of lenticular beds of calcareous, gray to pink-tan silt and clay, fine to coarse sand, and fine to coarse gravel. The sediments reflect two sources; arkosic sand and gravel beds derived from the west are interfingered in the northern part of the County with sand and gravel beds composed of gray to tan quartz and ironstone derived from Cretaceous rocks to the north. In subsurface only.	Contributes large supplies of good quality water to many municipal, irrigation, and industrial wells screened in multiple porous zones and penetrates the complete section of unconsolidated rocks.

Table 4. General description of the physical, chemical, and mineralogical properties of fine textured layers within the Equus Beds derived from field and laboratory analyses as well as descriptive well logs.

Properties	Description
Texture	Silty Clay, Silty Clay Loam, Sandy Clay, Clay, or Clay loam (in general clay contents are >35% and <60%)
Color	Dark gray 10yr 4/1 to Light olive gray 5y 6/2 colors are most common, but reddish brown to tan colors are also encountered. Redder colors are most common in the northern and eastern parts of the study area.
Redoximorphic Features	Reduced matrix colors, Mottles, and Fe and Mn concretions are common.
Organic Matter	The upper portion of these layers may represent the lower A and/or the upper part of the B-horizon of a paleosol. The top of the clay layer often has higher organic carbon contents than overlying or underlying materials. Organic carbon contents are typically >0.5% in the upper 10cm.
Carbonates	Generally found as nodules, root casts, soft white masses and filaments at or near the base of the layers. Some fine textured layers may have multiple zones of carbonate accumulation possibly indicating multiple periods of pedogenesis.
pH	Near neutral (6.5-7.5) at the top of the layer, moderately alkaline (8.0+) in horizons with maximum carbonate accumulation.
Salinity	Where the clay layer is at or near the surface, few surface drainage features exist, and accumulations of salts are common. These salt accumulations are evidenced by high electrical conductivities, increases in exchangeable sodium content and increased sodium adsorption ratios.
Stratigraphic Position	Most soils (upper 2 meters) are three storied. Fine sand (eolian)/ clay layer (alluvial ?)/coarse sand (alluvial). The thickness of the overlying sand varies from just a few centimeters to several meters. For this reason, the same clay layer is sometimes within the soil profile at one location and only found in the deeper vadose zone at another location a short distance away. Within the saturated zone they can occur anywhere but generally they are more common near the top of what appear to be fining upward sequences of alluvial sediment. The thickness of the clay layers varies from a few centimeters to >4 meters. The coarser sediments beneath the clay layers are generally clean, medium to coarse sand or fine gravel, but at a few locations fine sands similar to the eolian material at the surface have been found. It is also not uncommon to find stacked sequences of clay layers sandwiched between coarser sediments or alternating thin beds of sand and clay.
Mineralogy	Quartz and orthoclase (80-95%) dominate the sand fraction in all layers. The ratios of these and other minerals vary considerably between layers. The clay fraction within the clay layer is predominantly a mixture of montmorillonite, mica, and kaolinite. The relative amounts of these mineral are variable, but in general montmorillonite is most common. Many of these clay layers do have vertic properties as evidenced by large cracks, slickensides, and pressure faces.
Cation Exchange Capacity (CEC)	CEC is high. A typical range would be 20-35 milliequivalents/100g, (Ammonium Acetate at pH 7)
Base Saturation	High (85-100%)
Hydraulic Conductivity	Very Low (<.06in/hr, <10^{-5} cm/sec) The <.06 in/hr permeability class is the lowest found in modern soil surveys and soil coverages. Values as low as 0.000087in/hr have been measured in the study area.
Areal extent	Unknown, very common but not ubiquitous

In order to study the spatial variability of the stratigraphy in the Equus Beds we need to develop methods to map spatial patterns in important lithologic properties within the unsaturated and saturated zones. For example, it would be useful to know spatial patterns in occurrence and thickness for fine textured strata because of their strong influence on vertical and horizontal water movement. This sounds relatively simple but when you consider the magnitude of spatial stratigraphic variability in large alluvial systems, the immensity of the problem becomes obvious. Weerts and Bierkens (1993) have concluded from semivariogram analyses that to accurately map fluvial deposits in the Rhine-

Meuse floodplain using regular grid sampling methods, it would require a sampling interval of 25 –100 meters. This sampling density equates to a range of 100 to 1600 core samples per km^2 (259-4144 per mi^2). Townsend et al. (1996) concluded from transect sampling studies and semivariogram analyses that sampling intervals of 18 to 50 meters or less were required to accurately map spatial patterns in soil physical properties at a site in the Equus Beds. This level of sampling density can only be approached at a few densely sampled study sites. The time and monetary resources required for even selected site studies at this density of sampling are sparse.

An alternative approach to dense sampling is to utilize existing well log descriptions to create lithologic maps that have the potential to show broad-scale patterns of stratigraphic variability. Fortunately, the Equus Beds Aquifer has been the target for drilling of numerous water wells and test holes. The density of these sample points does not approach the density required to map the aquifer's stratigraphy in great detail, but it is sufficient to show general patterns of lithologic variability. The largest obstacle to the use of these well logs is that it is difficult to create simple, mapable variables from the complexity of the logs. To accomplish this a method for coding well log information was developed that simplified the lithologic descriptions into variables of uniform format within specified depth intervals.

Well Log Coding Details

There are several problems with the available well logs that make them difficult to use. First, the lithologic descriptions contained in the well logs were completed by a number of people from varying backgrounds over a period of years from the 1930's to 1990's. A wide variety of terminology has been used in these well log descriptions. Some of the descriptors are reasonably standard and others are the invention of the person logging the well. The wells within the study area described by geologists and published in KGS bulletins use the most consistent terminology (Williams and Lohman, 1949; Fent, 1950; Bayne, 1956; Layne and Miller, 1965A&B). Second, it is obvious that not all drillers in the area describe lithologic variations with the same skill or attentiveness. Descriptive logs from WWC5's for municipal water supply wells and monitoring wells tend to contain more detailed descriptions than most of the logs from domestic and stock wells. This is probably true because the water supply and monitoring well descriptions may have been supervised by engineers, geologists, or environmental scientists employed by the Kansas Department of Health and Environment, municipalities or environmental consulting firms. In any case, part of the screening process for well log selection for the lithologic coverages was to eliminate logs of dubious quality. Of the greater than 6,000 WWC-5 logs analyzed only about 1,600 were included in the lithologic coverages. Together with the 1,000 or so wells derived from KGS Bulletins the lithologic coverages for the greater Equus Beds study area (Harvey, Marion, McPherson, Reno, Rice, and Sedgwick Counties) included 2,690 well logs. Only about 1800 of these well log descriptions are included in the coverages for the general focus area of this study.

Another difficulty with using the well logs for stratigraphic analysis is related to the level of lithologic detail described in the well logs. Well logs from adjacent wells sometimes appear to be of equally good descriptive quality, but they may exhibit large differences in the number of strata described per unit of depth. The question which cannot be resolved from these situations is how much of detail or lack thereof in the logs is real and how much is not.

In order to use the data from the well logs to look at spatial patterns in texture (fine vs. coarse-textured sediments) a coding scheme was needed to simplify the more detailed logs while still utilizing the information in less detailed logs. Initially all lithologic descriptions were placed into four categories (gravels, sands, silts, clays). The assumption was that these four categories represented an abbreviated permeability continuum. Gravels were assumed to be more permeable than sands. Sands were assumed to be less permeable than gravels but more permeable than silts. Silts were assumed to be less permeable than sands and more permeable than clays. It became fairly obvious early in the analysis that while most drillers could easily differentiate between clays and sands, the differentiation between silts and clays was inconsistent. The same could be said for the differentiation between sands and gravels. To simplify the analysis, silts and clays were lumped together into one category called fines. Sands and gravels were also lumped together into a single category referred to as coarse textured sediments. The coarse textured sediments represent relatively permeable sediments that are assumed to represent the productive portions of the aquifer and, where exposed at the surface, effective recharge zones. The fines represent the less permeable strata that act as perching zones that can slow leaching rates and recharge through the vadose zone. They also represent aquitards and aquicludes within the aquifer.

A major problem with the above phase was the coding of layers with descriptions that did not fall neatly into one of the above categories. Strata described as sand with clay, sandy clay, and silty sand, etc. needed to be placed in one of the above categories in a consistent manor. The general rule adopted in these situations was that the descriptor is modifying a texture. In other words, a sandy clay is a clay with some sand grains therefore it belongs in the fines category. A silty sand is a sand with some finer silty sediment or thin silty layers in it. It is however, dominantly sand and therefore belongs in the coarse textured sediment category. Care was taken to code these layers in a consistent manner, but since there is no way of knowing what the describer really intended, there is a potential for some errors in coding due to these types of descriptions.

The next major hurdle in the coding of the well logs was to pick appropriate depth intervals for study. The depth intervals needed to be sufficiently thick that they represented a significant portion of the Equus Beds sediments but thin enough to show variability over relatively short distances. Another important consideration was the original intent of the coverage as mentioned earlier. The focus was placed on fine textured layers that were assumed to have the strongest effect on non-point source pollutants entering the aquifer. The greatest detail was therefore needed in the shallower depth intervals.

Initially the coded lithologic variables were entered into a spreadsheet in six depth intervals (0-10', 0-25', 0-50', 0-100', >100', total core depth). For each depth interval the thickness of fines described in the well log was recorded.

By subtracting each shallower depth interval from the next deeper interval (i.e. fines 0-25 minus fines 0-10) the following depth intervals for stratigraphic analysis were obtained: 0-10', 10-25', 25-50', 50-100', >100', and total thickness of fines for the entire log. For each of these depth intervals the percentage of that depth interval that was described as fines was calculated. Tables 5a and 5b provide an example of the level of detail in a *high quality* well log description published in a KGS Bulletin and the coded version of the log found in the ARC/INFO coverages. Tables 6a and 6b show a less detailed well log description published in a KGS Bulletin and its coded version.

Table 5a. An example of a well log with a very detailed lithologic description from Williams and Lohman (1949). Layers within the core description that were coded as fines are shaded gray.

Sample log number 249 of a test hole at the NE cor. NW1/4 sec. 16, T. 24s, R2w., Harvey County; drilled by City of Wichita, 1938. Surface Altitude, 1,402.2 feet. (Samples studied by Charles C. Williams.)		
Quaternary — Pleistocene McPherson Formation	Thickness feet	Depth feet
Silt, brown to buff	5	5
Sand, fine to coarse; contains brown silt	1	6
Silt and clay, dark gray	3	9
Gravel, fine to coarse, and coarse to fine sand	2	11
Sand, coarse to medium, and fine to medium gravel,	7	18
Silt, gray, and very fine to fine sand	12	30
Sand, medium to very fine	2	32
Silt and clay, gray to buff	5	37
Sand, fine to medium	1	38
Sand, coarse to medium, and fine gravel	12	50
Gravel, coarse to fine, and coarse sand	6	56
Sand, coarse to medium and fine gravel	3	59
Gravel, fine to medium, and coarse sand	7	66
Sand, coarse to medium	6	72
Silt and clay, gray to buff	14	86
Silt, buff; contains nodules of calcium carbonate	10	96
Sand, coarse to medium, and fine gravel	4	100
Gravel, fine to medium, and coarse sand	25	125
Sand, coarse to medium, and fine gravel	8	133
Gravel, fine to medium, and coarse sand	2	135
Sand, coarse to medium, and fine gravel	13	148
Silt, buff, calcareous	5	153
Sand, fine to coarse	8	161
Gravel, fine to medium, and coarse sand	5	166
Silt, light gray, and very fine to fine sand	3	169
Silt and clay, dark gray	19	188
Sand, coarse to medium, and fine gravel	3	191
Gravel, fine to medium, and coarse sand	5	196
Sand, coarse to medium, and fine gravel	4	200
Gravel, fine, and coarse to medium sand	2	202
Permian — Leonardian Wellington Formation		
Shale, weathered, calcareous, gray	3	205
Shale, calcareous, soft, gray	8	213
Shale, calcareous, gray	9	222

Table 5b. The coded version of the above log.

Depth Interval	Fines Thickness	Fines Percent
F10 (0-10')	8	80
F1025 (10-25')	7	47(46.7)
F2550 (25-50')	10	40
F50100 (50-100')	24	48
Fg100 (>100')	27	27(26.5)
Fall (0 to bottom of log)	76	38(37.6)

Table 6a. An example of a well log with a less detailed lithologic description and some problem descriptions from Williams and Lohman (1949). Layers within the core description that were coded as fines are shaded gray.

Driller's log of test hole number 253 at the SE cor. of the NE1/4, sec. 16, T. 24S. R.2 W., Harvey County; drilled for the City of Wichita, 1938. Surface altitude 1,403 feet. (Courtesy Black and Veatch, engineers.)		
Quaternary — Pleistocene and Recent Alluvium and McPherson formation	Thickness feet	Depth feet
Soil	5	5
Sand	40	45
Gravel	10	55
Clay and Gravel	30	85
Clay	20	105
Sand and Clay	75	180
Permian — Leonardian Wellington Formation		
Clay and Shale	5	185
Shale	1	186

Table 6b. The coded version of the above log.

Depth Interval	Fines Thickness	Fines Percent
F10 (0-10')	0	0
F1025 (10-25')	0	0
F2550 (25-50')	0	0
F50100 (50-100')	45	90
Fg100 (>100')	5	6
Fall (0 to bottom of log)	50	27.8

Another problem with the well log descriptions becomes obvious in table 6a. The first layer is simply described as soil and no texture is given. In some cases a color description is included but that is all. This practice is most prevalent in well logs included in KGS Bulletins that were originally described by personnel from Layne–Western, Black and Veatch, engineers, or the Kelly Well Company. It is also common in well logs on WWC5 forms. There are at least three choices to deal with this type of description: 1) Drop the logs with these types of descriptions from the coverages completely; 2) Devise some type of consistent method for applying the appropriate code to the affected layers and label the affected logs in the database; 3) Drop the logs with these types of descriptions from the coverage(s) affected by the depth interval of the descriptions but keep them in the coverages for the other depth intervals. After much deliberation it was decided to apply a combination of numbers 2) and 3).

A first consideration was the thickness of the soil layers described. Thickness varied from 1 to 15 feet. All of the logs with more than 5 feet described as soil without an indication of texture were eliminated from the shallow stratigraphy coverages unless there was enough evidence from other sources to make a reasonable assumption regarding texture. There were three clues that were used to infer texture. 1) If the soil description included a color it is usually somewhat indicative of texture. Gray and black colors are most common in fine textured sediments. Tan colors are sometimes indicative of silty layers. Browns, yellows and oranges are most common in coarser textured soils but there are exceptions especially in the northern and eastern portions of the study area. 2) The texture and color of the layer described beneath the soil layer was sometimes helpful. If the soil was described as tan and the layer beneath it was describe as tan silt then the soil layer was classified as fines. In other words it was assumed that the tan soil was formed in tan silt. 3) The formation description was also helpful in some cases. For instance if the soil layer was included in the depth interval in the logs that was generally described as Quaternary Dune Sand it is logical to assume that the soil formed in dune sand and should not be in the fines category. If a reasonable estimate of the texture of the soil layer could not be determined from these clues and/or the soil layer was ≥ 6 feet, the log in question was removed from the shallowest coverage (0-10' interval).

Reasons for Selecting Depth Intervals

The five depth intervals were chosen to represent characteristic portions of the Equus Beds that should influence nitrate leaching through the vadose zone and nitrate transport within the aquifer. Throughout the Equus Beds Aquifer the depth to the water table ranges from <10' to about 50' below ground surface. In wet years, the water table may be at or near the land surface in certain locales. In very dry years, the water table may be lowered significantly (below 50') in areas of heavy pumpage, but outside of areas of heavy pumpage, the water table is usually encountered within 10 to 25' of the ground surface. The 0-10' depth interval is designed to characterize the near surface sediments that make up the soil and shallow vadose zone. The 10-25' interval is designed to represent the lower vadose zone below the root zone, the capillary fringe, and possibly the uppermost parts of the aquifer. The 25-50' interval was designed to represent the upper or shallow portion of the Equus Beds Aquifer. The 50-100' was designed to represent the intermediate portion of the aquifer. The depth interval >100' feet represents the deep aquifer. The three shallowest depth intervals should have the strongest influence on nitrate movement into the Equus Beds Aquifer, while the two deepest intervals should have the strongest influence on lateral and vertical movements of nitrate and other contaminants such as chlorides within the aquifer.

Attributes in the Well Log Coverages

In addition to the lithlogic information, attributes in the well log database include the longitude and latitude coordinates for each well log location, the legal description, the source (WWC5 or KGS Bulletin), the elevation of the land surface at the well location if known, the depth to consolidated bedrock, and the elevation of the bedrock. To facilitate the use of the lithologic variables for later indicator variography and indicator kriging, a set of binary codes was also calculated. In these columns, a zero or a 1 was entered into the spreadsheet based on the percentage of fines in each depth interval and a predetermined cutoff. These indicator variables were determined for simple presence or absence, and for intervals of 10% from 10 to 100% fines.

Data from the spreadsheets were converted to attributes in the ARC/INFO point coverages by saving the spreadsheets in DBASEIV format and converting the resulting database files to ARC/INFO data tables using the <dbaseinfo>

command in ARC. The new tables were then attached to the point attribute files for the existing well point coverages using the <joinitem> command in ARC/INFO. The initial coverage contained all of the coded and calculated lithology variables for all depth intervals. In the final versions, a separate coverage was created for each depth interval to simplify overlaying coverages and to make the attribute tables for the coverages less confusing. The six resulting coverages are named based on the attributes they contain. For example the coverage containing the fines attributes for the upper ten feet is named f10n_hv. The coverage for the 10-25 foot interval is called f1025_hv. The coverage for the 25-50 foot interval is called f2550_hv. The coverage for the 50-100 foot interval is called f50100_hv. The coverage for the >100 foot interval is fg100_hv. The coverage containing the percentage of fines described in the entire well logs is called falln_hv. For all coverages the hv at the end of the coverage name signifies that they are projected in the Lambert projection found in Appendix A. Appendix B contains example tables showing the attributes contained in each coverage.

Most of the data found in the coverage databases is uniform. For instance, each database has a –id (i.e. f10n–id), a set of longitude and latitude coordinates, an ID#, the township (T), range (R), section (S), and subdivision (USPLSS legal description), the Source, a set of indicator variables, and the x-y projected coordinates (x-feet and y-feet). The –id is a sequential reference number from each ARC/INFO point coverage. The ID# is a master identification number which corresponds to the original datasheets on which the well log information was recorded. If a question arises about a particular well log this number can be used to find the well log from which it originated. The source indicates where the individual logs came from. The indicator variables are for simple presence or absence of a fine textured layer (PA) and for 10 percent cutoff intervals from 10 percent (f10) to 100 percent (f100). In other words, in the PA column of a database a 0 indicates that no fine textured material was described in the well logs for that depth interval. A 1 indicates that a fine textured layer was present. In the F10 column, a 0 indicates that less than 10 percent of the depth interval was described as consisting of fine textured sediment, and a 1 indicates that greater than 10% of the depth interval was described as consisting of fine textured sediment.

The coverages do not contain the same number of well logs (Table 7) because the thickness of unconsolidated sediment varies considerably throughout the general study area. Depth to bedrock (DTBR in the fg100_hv and fall_hv coverages) varies from 2 to 321 feet. Well logs were only included in a coverage if their descriptions contained information for the entire depth interval. For instance, the f10n_hv coverages contain only those well logs for which a description of the upper ten feet was included. If the depth to bedrock was described as less than 10 feet the well log was not included in the f10n_hv coverage. By the same token a well log with a depth to bedrock of 15 feet would be included in the f10n_hv and falln_hv coverages, but not in any other coverages because it does not have descriptive information for the entirety of any other depth interval. An additional constraint was placed on well logs to be included in the fg100_hv and falln_hv coverages. Well logs in these coverages are restricted to those that penetrated the entire unconsolidated sequence (i.e. they must reach bedrock). For these reasons, the actual number of well logs in the coverages ranges from 1822 (f10n_hv) to 320 (fg100_hv). This also means that the same well log point locations are not included in all of the coverages because some logs meet the criteria for inclusion in one coverage, but not for others.

Table 7. Coverage names and the total number of well logs included in each coverage

Coverage Name	Number of Well Logs
F10n_hv	1822
F1025_hv	1676
F2550_hv	1196
F50100_hv	636
Fg100_hv	320
Fall_hv	959

Appendix A: Map projection details

Projection: Lambert

Units: Feet

1st Standard Parallel: 38 00 00

2nd Standard Parallel: 38 07 30

Central Meridian: -97 34 30

Latitude of Projections Origin: 37 52 30

False Easting: 0

False Northing: 0

Although not indicated in the projections the datum used in the coverages is NAD27.

Appendix B. Example tables showing the variables in the stratigraphy coverages.

F10n.xls (f10n_hv)

f10n-id	Longitude	Latitude	ID#	T	R	S	subd	Source	SiC10	F10	PA10	I10	I20	I30	I40	I50	I60	I70	I80	I90	I100	x-feet	y-feet
1	-97.352791	38.231441	99	21S	1E	17	BBBB	Williams&Lohman 1949	0	0	0	0	0	0	0	0	0	0	0	0	0	63832.625	129876.914
2	-97.426826	38.232388	100	21S	1W	9	DDDD	Williams&Lohman 1949	0	0	0	0	0	0	0	0	0	0	0	0	0	42564.348	130179.047
3	-97.549820	38.187714	2218	21S	2W	33	BAB	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	7237.637	113877.320
4	-97.344276	38.165398	2061	22S	1E	5	CAA	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	66338.211	105831.992
5	-97.370338	38.121857	2082	22S	1E	19	CBB	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	58879.727	89958.508
6	-97.397797	38.160084	1002	22S	1W	2	DCC	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	50953.660	103863.102
7	-97.430008	38.158356	1041	22S	1W	9	AAB	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	41692.504	103217.758
8	-97.395592	38.143742	1054	22S	1W	14	ABA	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	51599.152	97913.125
9	-97.418716	38.116566	1145	22S	1W	22	CDD	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	44964.969	88004.711
10	-97.664238	38.144020	1248	22S	3W	16	BBB	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	-25665.422	97977.047

F1025.xls (f1025_hv)

f1025-id	Longitude	Latitude	ID#	T	R	S	subd	Source	SiC25	F1025	PA1025	I10	I20	I30	I40	I50	I60	I70	I80	I90	I100	x-feet	y-feet
1	-97.344276	38.165398	2061	22S	1E	5	CAA	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	66338.21	105832
2	-97.430008	38.158356	1041	22S	1W	9	AAB	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	41692.5	103217.8
3	-97.395592	38.143742	1054	22S	1W	14	ABA	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	51599.15	97913.13
4	-97.658516	38.103027	1310	22S	3W	28	CD	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	-24033.1	83047.58
5	-97.423515	38.073044	1341	23S	1W	3	CCD	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	43610.09	72153.57
6	-97.480446	38.051243	2602	23S	1W	18	BCC	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	27228.76	64192.9
7	-97.475914	38.011253	1515	23S	1W	31	BAC	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	28549.32	49631.9
8	-97.590546	38.053261	1582	23S	2W	18	BCB	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	-4476.56	64914.28
9	-97.579132	38.047886	1585	23S	2W	18	DBD	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	-1189.97	62956.63
10	-97.581398	38.040596	1588	23S	2W	19	ABC	WWC5	0	0	0	0	0	0	0	0	0	0	0	0	0	-1842.7	60302.01

F2550.xls (f2550_hv)

f2550-id	Longitude	Latitude	ID#	T	R	S	subd	Source	SiC50	F2550	PA2550	I10	I20	I30	I40	I50	I60	I70	I80	I90	I100	x-feet	y-feet
1	-97.499626	38.231598	108	21S	2W	13	BBBB	Williams&Lohman 1949	2	0	0	0	0	0	0	0	0	0	0	0	0	21652.14	129866.3
2	-97.568207	38.175041	2216	21S	2W	32	CDC	WWC5	9	0	0	0	0	0	0	0	0	0	0	0	0	1952.947	109261.6
3	-97.701241	38.231483	121	21S	3W	18	BBBB	Williams&Lohman 1949	16	0	0	0	0	0	0	0	0	0	0	0	0	-36264.3	129840.5
4	-97.545303	38.165909	1180	22S	2W	4	DBB	WWC5	6	0	0	0	0	0	0	0	0	0	0	0	0	8538.405	105937.2
5	-97.536011	38.147816	2570	22S	2W	10	CCB	WWC5	23	0	0	0	0	0	0	0	0	0	0	0	0	11212.99	99349.31
6	-97.524414	38.147789	2571	22S	2W	10	DCA	WWC5	13	0	0	0	0	0	0	0	0	0	0	0	0	14548.1	99341.19
7	-97.517433	38.136864	1191	22S	2W	14	CBB	WWC5	7	0	0	0	0	0	0	0	0	0	0	0	0	16558.21	95363.77
8	-97.556702	38.144173	1197	22S	2W	17	AAA	WWC5	20	0	0	0	0	0	0	0	0	0	0	0	0	5262.711	98020.81
9	-97.586151	38.11871	1204	22S	2W	19	CDB	WWC5	19	0	0	0	0	0	0	0	0	0	0	0	0	-3208.24	88747.81
10	-97.648148	38.116734	2628	22S	3W	21	DDD	WWC5	11	0	0	0	0	0	0	0	0	0	0	0	0	-21045.5	88036.31

F50100.xls (f50100_hv)

f50100-id	Longitude	Latitude	ID#	T	R	S	subd	Source	SiC100	F50100	PA50100	I10	I20	I30	I40	I50	I60	I70	I80	I90	I100	x-feet	y-feet
1	-97.632874	38.23175	118	21S	3W	15	AABB	Williams&Lohman 1949	47	0	0	0	0	0	0	0	0	0	0	0	0	-16624.9	129918.3
2	-97.619041	38.19632	2226	21S	3W	26	ACCC	WWC5	36	0	0	0	0	0	0	0	0	0	0	0	0	-12657.6	117013.3
3	-97.666702	38.182007	2240	21S	3W	32	ADD	WWC5	37	0	0	0	0	0	0	0	0	0	0	0	0	-26360.5	111811.1
4	-97.664406	38.182011	2244	21S	3W	33	BCC	WWC5	43	0	0	0	0	0	0	0	0	0	0	0	0	-25700.4	111811.9
5	-97.6828	38.151234	1270	22S	3W	8	CBB	WWC5	35	0	0	0	0	0	0	0	0	0	0	0	0	-31001	100609.6
6	-97.68277	38.116718	2637	22S	3W	20	CCC	WWC5	32	0	0	0	0	0	0	0	0	0	0	0	0	-31006.8	88040.45
7	-97.684868	38.102158	2636	22S	3W	30	DDD	WWC5	27	0	0	0	0	0	0	0	0	0	0	0	0	-31616.7	82738.74
8	-97.444046	38.036655	1401	23S	1W	21	BCC	WWC5	40	0	0	0	0	0	0	0	0	0	0	0	0	37718.3	58893.54
9	-97.425476	38.014858	1507	23S	1W	27	CCC	WWC5	14	0	0	0	0	0	0	0	0	0	0	0	0	43079.72	50964.07
10	-97.480453	38.011265	2595	23S	1W	31	BBC	WWC5	45	0	0	0	0	0	0	0	0	0	0	0	0	27241.37	49634.71

Fg100.xls (fg100_hv)

fg100-id	Longitude	Latitude	ID#	T	R	S	subd	Source	DTBR	Thick	SiCAll	Fg100	PAg100	I10	I20	I30	I40	I50	I60	I70	I80	I90	I100	x-feet	y-feet
1	-97.563675	38.202297	112	21S	2W	29	ABB	Williams&Lohman 1949	107	107	54	0	0	0	0	0	0	0	0	0	0	0	0	3254.579	119187.4
2	-97.567123	38.201401	114	21S	2W	29	BA	Williams&Lohman 1949	124	124	26	0	0	0	0	0	0	0	0	0	0	0	0	2263.587	118860.8
3	-97.5746	38.202774	115	21S	2W	30	AAAA	Williams&Lohman 1949	141	141	57	0	0	0	0	0	0	0	0	0	0	0	0	114.887	119360.8
4	-97.609879	38.231812	117	21S	3W	13	BBBB	Williams&Lohman 1949	142	142	41	0	0	0	0	0	0	0	0	0	0	0	0	-10019.3	129937.2
5	-97.619041	38.19632	2226	21S	3W	26	ACCC	WWC5	135	135	36	0	0	0	0	0	0	0	0	0	0	0	0	-12657.6	117013.3
6	-97.616081	38.175045	2248	21S	3W	35	DCD	WWC5	101	101	44	0	0	0	0	0	0	0	0	0	0	0	0	-11810.2	109265.5
7	-97.614944	38.177773	2250	21S	3W	35	D	WWC5	104	104	55	0	0	0	0	0	0	0	0	0	0	0	0	-11483	110258.6
8	-97.512924	38.160515	1173	22S	2W	2	CDC	WWC5	100	100	75	0	0	0	0	0	0	0	0	0	0	0	0	17849.4	103977.5
9	-97.533745	38.162308	1176	22S	2W	3	CCA	WWC5	103	103	56	0	0	0	0	0	0	0	0	0	0	0	0	11862.31	104627
10	-97.581894	38.15876	1184	22S	2W	7	ABB	WWC5	104	104	67	0	0	0	0	0	0	0	0	0	0	0	0	-1982.34	103332.6

Falln.xls (falln_hv)

falln-id	Longitude	Latitude	ID#	T	R	S	subd	Source	DTBR	ELEV.	BR-ELEV	ClayAll	Fall	PAall	I10	I20	I30	I40	I50	I60	I70	I80	I90	I100	x-feet	y-feet
1	-97.352791	38.231441	99	21S	1E	17	BBBB	Williams&Lohman 1949	21	1524	1503	0	0	0	0	0	0	0	0	0	0	0	0	0	63832.625	129876.914
2	-97.344276	38.165398	2061	22S	1E	5	CAA	WWC5	35	1505	1470	0	0	0	0	0	0	0	0	0	0	0	0	0	66338.211	105831.992
3	-97.397797	38.160084	1002	22S	1W	2	DCC	WWC5	15	1482	1467	0	0	0	0	0	0	0	0	0	0	0	0	0	50953.660	103863.102
4	-97.430008	38.158356	1041	22S	1W	9	AAB	WWC5	30	1490	1460	0	0	0	0	0	0	0	0	0	0	0	0	0	41692.504	103217.758
5	-97.418716	38.116566	1145	22S	1W	22	CDD	WWC5	18	1440	1422	0	0	0	0	0	0	0	0	0	0	0	0	0	44964.969	88004.711
6	-97.418716	38.116566	1146	22S	1W	22	CDD	WWC5	21	1440	1419	0	0	0	0	0	0	0	0	0	0	0	0	0	44964.969	88004.711
7	-97.408981	38.033550	1403	23S	1W	22	DADA	WWC5	40	1435	1395	0	0	0	0	0	0	0	0	0	0	0	0	0	47819.895	57778.914
8	-97.388916	38.031235	1467	23S	1W	24	CCB	WWC5	9	1425	1416	0	0	0	0	0	0	0	0	0	0	0	0	0	53601.172	56946.656
9	-97.393440	38.014874	1504	23S	1W	26	DDC	WWC5	46	1416	1370	0	0	0	0	0	0	0	0	0	0	0	0	0	52309.617	50986.070
10	-97.377472	37.930088	1789	24S	1W	25	DCA	WWC5	2	1415	1413	0	0	0	0	0	0	0	0	0	0	0	0	0	56975.906	20120.762

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